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Relation between stability of slope and the urban density: Case study

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Abstract

The main of this work is to present a study that permits to obtain a quantitative assessment of the urban density under seismic condition on sloped land. The research of relation between the bearing capacity of soil and the urban density is based on the modeling of the physical weight of an urban composition and the limit capacity of soil. The referential urban shape is assimilated to a planar parcel situated in one big number of square plots. The vertical component of earthquake acceleration is considered as additional force to the static weight of the buildings, and the horizontal component is taken as additional force that increases the lateral force of slope. This approach permits the analysis of the global slope stability of an urbanized land. The elaboration of this study is a response to the disaster risk reduction that sustainable urban development recommends.
The urban composition is characterized by a mathematical system composed by two equations represented respectively by the urban density and the site coverage ratio. This system is indeterminate because there is one unknown: the building footprint; and one correlation: the plot surface. To solving this problem, it is demanded to use loop procedure, and finite difference method that consists in introducing a random value of density, and then to comparing the obtained density with the introduced value.
The study begins with the evaluation of the weight of the floors, and then follows with the distribution of the weight of all buildings, that composes one orthogonal parcel, on the global surface of parcel. This repartition gives an equivalent uniform charge. Therefore, by this simplification, it is possible to resolve the problem by static method. At last, the study finishes by the presentation of graphs showing the relation between the soil bearing and the urban density.

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1. Introduction

During the last few years, the focus of landslide research has moved beyond process investigations and stability assessment towards consequence analysis. The integrated assessment of both hazards is becoming accepted as practice in the management of risk reduction. Varnes [1] was one of the early advocates of this approach to landslide research and engineering practice. The requirements for integrated hazard and risk in the engineering studies are becoming systematized in the standard references as Turner and Schuster [2], Cruden and Fell [3]. Thus, in common usage, the term ‘hazard’ has two different meanings: first, the physical process or activity that is potentially damaging; and second, the threatening state or condition, indicated by likelihood of occurrence. The consequences of hazard occurrence can be great or small, as well as direct or indirect; the latter linked to the primary impact by a chain of dependent reactions. The important concept of "“risk” can thus be seen as having two components: the likelihood of something adverse happening and the consequences if it does. The level of risk, then, is the combination of the likelihood of something adverse occurring and the consequences if it does. The level of risk thus results from the intersection of hazard with the value of the elements at risk by way of their vulnerability. The figure 1 gives the conceptual relationship between hazard, vulnerability and risk.

Hazard + Vulnerability = Risk

Fig.1. Conceptual relationship between hazard, vulnerability and risk

1.1. *Background on Landslide*

Landslips, the result of slope failure, represent one of the most frequently experienced natural hazards in Algeria. This study extends upon two previous studies that addressed the improvement of practice in the management of landslip risk, [4]. The focus of this study is to understand how slope stability is considered in current land use and planning practice. For the management of landslip risks to be improved, it is necessary to have an understanding of how actual planning practice is influenced by considerations of slope stability. In reviewing land use planning several statutes need to be considered [5]. Each can be linked through the Regional Policy Statement from which are devised both Regional and District Plans.

1.2. Background on Urban Density

Construction of buildings and development of cities on steep-slope terrain has been problematic throughout the ages. The impact on the environment can be severe from the disturbance of the fragile slopes, particularly when poor soil conditions prevail. Mud slides are a risk with appreciable loss of life and high costs, and in earthquake prone areas the potential for disaster increases. The Expansion of Urbanization is facilitated by the low cost of the sloped land, and allows a continuous means of growth on steep sloped terrain. This type of land can be appropriate for multi-story buildings, high-density forms, and offers an opportunity to build an adapted urban composition. The debate on use of hillsides is justified by the Algerian topography of Land. The lack of new areas for urbanization suggests the use of an Innovative approach in relation with Environment. The challenge is to anticipate the future demands in urban growth by a sustainable development that takes in account the term vision [6], [7] and [8].

Density is one of the most used dimensions to assess urban sprawl. This affirmation is illustrated in specialized and popular literature [9] and show that sprawl became a metaphor for a model of suburban urban expansion. The urban growth and sprawl and the environmental risks in Algeria is like others urban agglomerations in Africa or Brazil. This urban growth demands new lands, generates urban risks [10]. This phenomenon requires a new approach in the future urban design [11] for to satisfy the problematic of the urban sustainable development. To enhance the design of the urban composition, it is necessary to propose a methodology that takes in account the stability of sloped land.

The disasters siphon the national resources by their effects, and must not become a necessary and inevitable consequence of development [12].

1.3. Urban Patrimony and risks

Protection of Urban Patrimony is a priority for all societies. For the European countries, a European Centre: the European University Centre for the Cultural Heritage (CUEBC) was created in Ravello. On 15-17 November 1989, a colloquy on the Protection of the Architectural Heritage against Natural Disasters was jointly organised at the European University Centre for the Cultural Heritage in Ravello by the Intergovernmental Steering Committee for integrated Conservation of the Historic Heritage and the EUR-OPA Major Hazards Agreement. On 23 November 1993, the Committee of Ministers of the Council of Europe adopted a Recommendation N° R (93) 9 on the Protection of the Architectural Heritage against Disasters. In 1996, many non-governmental Organizations founded the International Committee of the Blue Shield (ICBS). In Kobe and Kyoto a Declaration was adopted to enhance international collaboration to minimizing losses of cultural heritage due to disasters. A manual for risk preparedness for the cultural heritage has been prepared and was published by International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM) in 1998.

2. Presentation of the problem

The technical literature no gives a detailed guidance for the location of the building near a slope. The designer has a lot of difficulties to solve such a problem.

2.1. Characteristics of the site

The site is characterized by a mountain environment and by two geological sections. The first section have clay and sand layer at the surface and a clay layer in deep, and the second section has a brittle rock layer (schist) at the surface and a clay layer in deep.

2.2. Goal and demarche

The principal goal is to find a solution that determines an approximation of the maximal load that can support sloped land. This maximal load is assimilated to a uniform surfacic charge generated by the load of buildings. In the urban Planning, every plot is characterized by a density of dwellings and an urbanized area. In case of individual house, the Administration requires the respect of the elevation and the coefficient of soil occupation. For the collective urbanization carried out under operational urbanism, the specifications concern the density and the footing-print of the buildings. To concretize this objective, a slope stability analysis under the building action is necessary. They are many methods for the study of slope stability based on the shape of the failure (circle, logarithmic, etc). The stability of the slope is carried out using the probability of failure of a slope using the limit equilibrium method. For this work, the approach of circular failure is adopted [13]. However, Bishop's method is implemented in most programs and was used as a reference method for comparison between programs and search techniques. The results of this study concerns two axes: provide some fundamental background information needed for City staff to understand and interpret the phenomena on the stability of natural slopes; and contribute to provide a guideline on the state-of-practice of the stability of natural slopes. A factor of safety is really an index indicating the relative stability of a slope. The ratio of strength (the resistance) R and load (the solicitation) S gives the safety factor (FS). When the safety factor (FS) is smaller than 1.0, the slope is unstable. Considering a circular slip surface, there are several important methods, developed by Fellenius, Taylor, Bishop and others, that can help determine the safety factor (FS). All these methods use several simplifying assumptions. In this study Bishop's method will be considered because they are the most frequently used method in engineering practice.

2.3. Presentation of the sloped land and the setting up of buildings

Most authors, specialist in the mechanics of soils and urban engineering, recommend to give an angle equal from 40 at 45 degrees and an distance, between the limit of slope and the building, necessary for the servitude and maintenance of the building, equal from 2.0 at 3 meters. These values are given without taking into account the number of levels, the soil bearing capacity and the stability of slope. The absence of one simple tool which can resolves the setback distance between slope and buildings justifies this study. The case study is a natural slope, composed by two independent layers, and supports several buildings. The phenomenon of erosion is not taken in account. Figure 2 shows the setting up of buildings in terraces when the land is sloped.

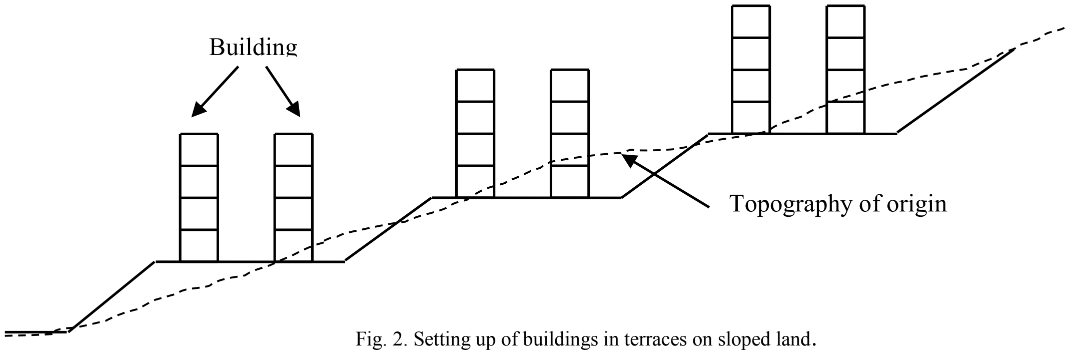


Fig. 2. Setting up of buildings in terraces on sloped land.

3. Resolution

The beginning of project is very important. The engagement of all actors is required. There are three phases: Master plan, Plan of mass and detail plan. For any phase, there is adequate specialist, and the planer town is the driver of the staff. In practice, three cases of urban density are analyzed: compact model, mi-compact model and spaced model. The different spaces affected to every building make the difference between each case.

3.1. Evaluation of the urban density

The elements enabling a freely urban composition are cited in the following references: the recommendations of the Algerian manuals of urbanism and construction [14], the book of Zeitoun [15], the three tomes of Zucchelli [16], [17], [18] and the works of EL KECHEBOUR [19]. The urban composition operation is realized by using two coefficients: the dwelling density (d) and the site coverage ratio (S.C.R). The density shows the number of dwellings setting on a hectare area (10000 m2). In this area there are all spaces with their functions. The site coverage ratio (S.C.R) shows the organization of the buildings and the dwellings in the vertical and horizontal plan. The using of these coefficients can be applied for two scales: one building or one plot (mass plan). For one building, the system is following:

$$\begin{cases} d = \dfrac{N}{Ass} 10000\ m^2 & (1) \\ S.C.R = \dfrac{E}{Ass} & (2) \end{cases}$$

d: dwelling density
S.C.R: site coverage ratio
N: Number of dwellings on the area of the site.

E: Building footprint
ass: building compound.10.000 m2: hectare surface.

Remaark: for one plot, the precedent equations (1) and (2) give this form:

$$\begin{cases} \mathrm{d}=\dfrac{\mathrm{N}}{\Sigma \mathrm{ass}}10000\ \mathrm{m2}=\dfrac{\mathrm{NT}}{\Sigma \mathrm{ass}}10000\ \mathrm{m2} & (3) \\ \mathrm{S.C.R}=\dfrac{\mathrm{E}}{\Sigma \mathrm{ass}}=\dfrac{\mathrm{m^*E}}{\mathrm{m^*ass}}=\dfrac{\mathrm{ET}}{\mathrm{ASS}} & (4) \end{cases}$$

m: Number of buildings (same type),
ASS = m.ass: building compound of the total parcel area
ET = m.E : Total surface of the Building footprint.

3.2. Evaluation of the Charges and calculations

The vertical load generated by each story is taken approximatively to be one ton by square meter (1 t/m2) and the global vertical load by building equal to the sum of the number of stories.The intermediate urban density expresses the number of dwellings into one hectare. Table 1 gives the values of k_h and k_v defined by the Algerian paraseismic code [20] according to the group of use considered for zone of mean seismicity (zone IIa), and table 2 defines the classification of works. The considered site is classified by the Algerian paraseismic rules like a zone of mean seismicity (zone IIa). The horizontal and vertical seismic coefficients, k_h and k_v, taken into account in seismic slope stability calculations are: K_h= 0.5A.g and Kv= 0.3K_h, where A is the acceleration coefficient of zone and g=9.81m/s^2 the earth gravity acceleration.

Table 1. Values of the seismic **coefficients adopted [20].**

Zone	Group of use	A	Kh	Kv
IIa	1A	0.25	0.1250	0.0375
	1B	0.20	0.1000	0.0300
	2	0.15	0.0750	0.0225
	3	0.10	0.0500	0.0150

Table 2. Classification of works [RPA 99].

Classification of works:	Description
1A	works of vital importance (safety, hospitals)
1B	works of great importance (schools, mosques)
2	current works (dwellings, offices)
3	works of low importance (hangars)

Slope stability calculations were performed with the GeoStudio program for slope stability calculations in limit equilibrium method for a circular slip surfaces by the method of Bishop [21]. Seismic action is taken into account using pseudo-static approach. The principle of this approach consists on replacing the seismic action by an equivalent static action that takes account of the probable reaction of sloped soil mass. The pseudo-static efforts are represented by the two seismic coefficients kh and kv. Slope stability calculations program gives directly the safety factor of slipping of slope.. The land has a slope between 15 to 18% and the parcel is composed by two parallel lines of buildings. Between two building lines, there are green spaces. Around each building, there are pedestrian ways. Every building has six stories in elevation. The width of street is 6 meters and pedestrian way 2.5 meters. The parking are located along the streets oriented North-South. Figure 3 shows the static scheme of the resolution of the sloped land. The soil of land is composed of one layer of consolidated clay and sand.

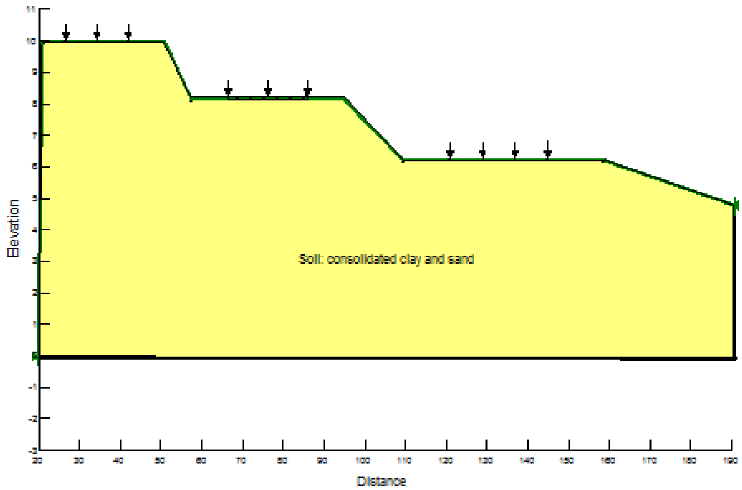


Fig. 3. Static scheme of the resolution of the sloped land

4. Case Study

Figure 4 gives the Scheme of the Master Plan of the urban project.

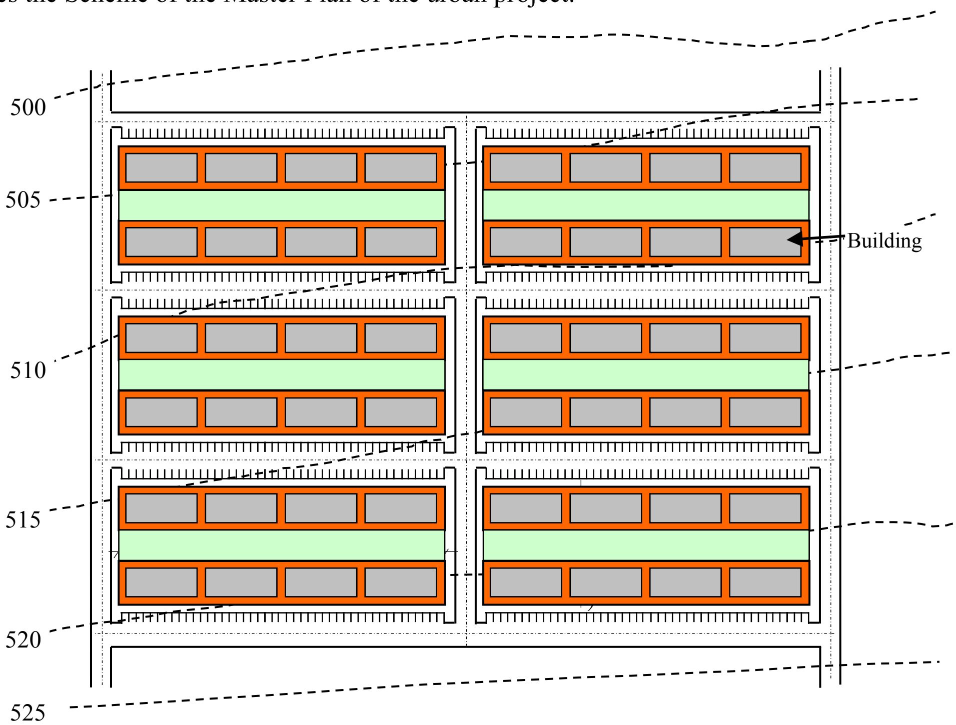
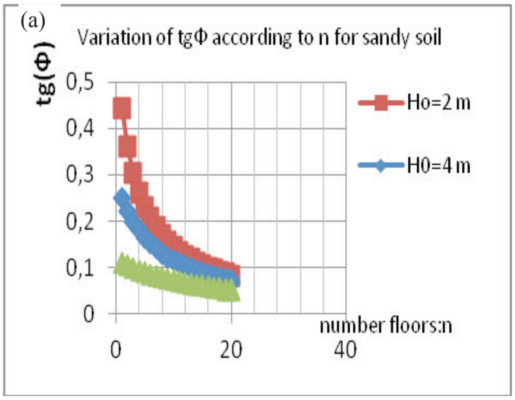


Fig. 4. Scheme of the Master Plan

5. Results and discussion

5.1. *Results*

The results are obtained under seismic condition in accordance with the Algerian code. Figure 5(a) shows the variation of the natural angle of repose of the slope according to the number of floors (n) and the elevation of the slope (H0). Figure 5(b) shows the variation of the factor of safety (Fs) according to the number of floors (n) and the elevation of the slope (H0).



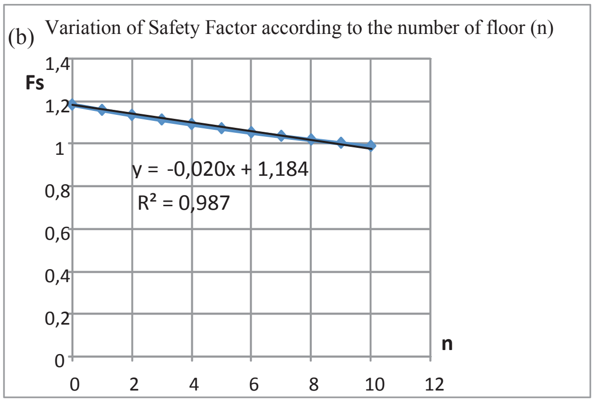


Fig. 5. (a): Variation of the natural angle of repose of the slope according to the number of floors (n) and the elevation of the slope (H0); (b): Variation of the factor of safety (Fs) according to the number of floors (n) and the elevation of the slope (H0);

5.2. *Discussion*

The assessment of the stability of a slope and the determination of the limit of hazard lands should consider the most conservative conditions. The method of limit equilibrium cannot give the deformations of soil. These situations correspond to the case where the values of safety factor vary from 1.2 at 1.0 under seismic conditions with moderate intensity. The simulations, with load surcharges, show that the site can supports six stories according to the figure 5. The calculations show also that the angle of slope for intermediate banks must be inferior to the first and the last bank. This difference is estimated to be 20 to30 %. Effectively the global stability of massif and the stability of terraces are not similar. However, to further increase security, it is recommended to verify the plasticization phenomenon by Plaxis software.
In this study, it was shown that limit equilibrium methods are reliable and can be used with confidence to investigate the stability of slopes.

Conclusion

The development of hazard lands must be restricted. They should be built with permanent structures and must be strongly controlled by geotechnical studies. In this study, it was shown that limit equilibrium methods are reliable and can be used with confidence to investigate the stability of slopes. The mastering of the knowledge of the implantation of buildings and the urban density on sloped land contributes to the mitigation of disaster risk and conflicts between administration and habitants. This type of urbanization is compatible with the vision of sustainable development.

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